SWRHL-19r

FINAL REPORT OF OFF-SITE SURVEILLANCE FOR THE PHOEBUS 1-A EXPERIMENT

by the
Southwestern Radiological Health Laboratory
U. S. Public Health Service
Department of Health, Education, and Welfare
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ABSTRACT

The Southwestern Radiological Health Laboratory provided off-site radiation surveillance in support of the Phoebus 1-A Experiment of June 25, 1965. This support consisted of tracking the effluent, monitoring radiation dosage to the off-site population and collecting environmental samples in downwind areas. Although off-site contamination occurred as a result of the Phoebus test, the data collected indicate that radioactivity levels did not exceed the safety criteria established by the Atomic Energy Commission for the off-site population.

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INTRODUCTION

As a part of the ROVER Program, testing and disassembling of a series of reactors designated Phoebus is being conducted by Los Alamos Scientific Laboratory at the Nuclear Rocket Development Station (NRDS). The subject of this report is the off-site surveillance provided by the Public Health Service (PHS) for the Atomic Energy Commission (AEC) in support of the Phoebus 1-A Experiment.

The Phoebus 1-A Experiment was conducted at Test Cell C on June 25, 1965 under conditions identified as Experimental Plan 4. The nominal operating power was 1100 megawatts. Other experimental plans generated such low power that there was no detectable off-site radioactivity. The reactor was tested in an upright position so that the hydrogen coolant exhausted upward along with escaping fission products. The test configuration is shown in Figure 1.

Under a Memorandum of Understanding with the Atomic Energy Commission, the U. S. Public Health Service conducts a program of radiological monitoring and environmental sampling in the off-site area surrounding the Nevada Test Site and the Nellis Air Force Range. The overall complex of the Nevada Test Site (NTS) and the Nellis Air Force Range (NAFR) includes the Nuclear Rocket Development Station and the Tonopah Test Range (TTR) and for simplicity will be called the test range complex throughout this report.

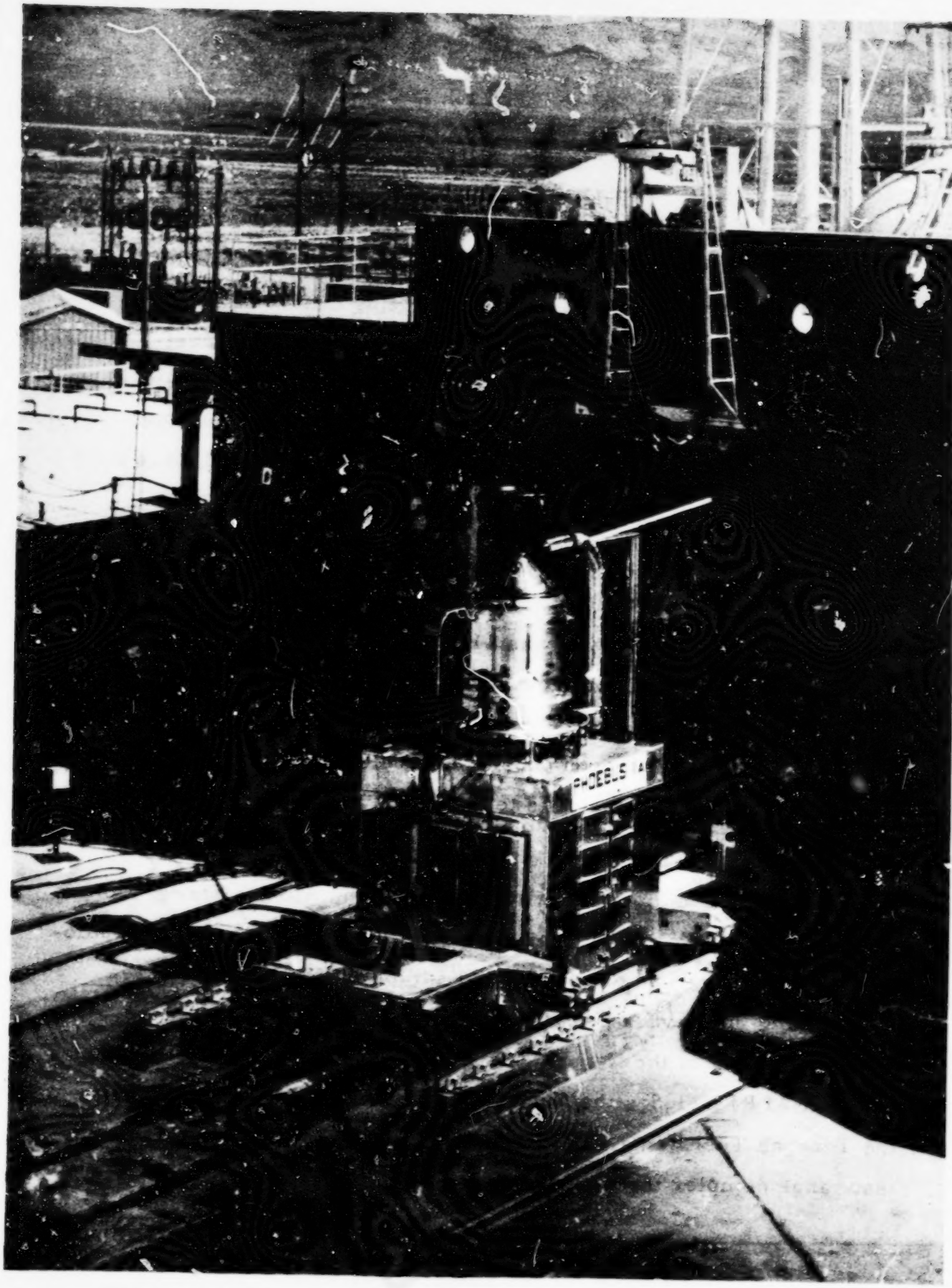

Figure 1. Reactor in testing position. (Photograph courtesy of Los Alamos Scientific Laboratory)

I. OPERATIONAL PROCEDURES

A. EXTERNAL MEASUREMENTS

1. Ground Monitoring

Ground monitors tracked the reactor effluent passage with portable instruments. Each monitor was equipped with an Eberline E-500B, a Precision Model 111 Standard "Scintillator", and a Victoreen Radector Model No. AGB-50B-SR.

The Eberline E-500B has a range of 0 to 200 milliroentgens per hour (mR/hr) in four scales with an external halogen filled GM tube and a 0 to 2000 mR/hr range from an internal Anton 302 tube. The Precision Model 111 "Scintillator" is used primarily for low level detection and provides for a range of 0 to 5 mR/hr in six scales. The Radector has a range of 0.05 to 50,000 mR/hr on two scales. This instrument employs an inert gas ionization chamber. Errors associated with these instruments are of the order of $\pm$ 20%.

2. Dose Rate Recorders

Eberline RM-11 dose rate recorders are placed at twenty-one stations around the test range complex. These recorders utilize a Geiger tube detector to document radiation levels at specific locations. The instrument has a 0.01 to 100 mR/hr range and the gamma dose rate is recorded on a 30-hour strip chart. The RM-11 is accurate to $\pm$ 20% as calibrated with a ^{137}Cs source.

3. Aerial Cloud Tracking

An Air Force U3-A aircraft, manned by two Public Health Service monitors equipped with portable instruments identical to those of the ground monitors, tracked the reactor effluent to position ground monitors. Public Health Service cloud sampling aircraft were also used as aids in cloud tracking. However, their primary purpose was cloud sampling in order to determine cloud size and inventory. The results of their sampling are reported separately by the SWRHL Engineering Development Program.

4. Film Badges

During June, the PHS maintained 86 film badge stations off the test range complex and assigned badges to 168 off-site residents. The badge used is made up of DuPont type 555 film. This film is accurate to $\pm$ 50% in the 20 to 100 mR range and $\pm$ 10% in the 100 to 2000 mR range. The lower limit of detectability is 20 mR.

B. ENVIRONMENTAL MEASUREMENTS

Ninety-five air samplers were routinely operated in the western United States at the time of these experiments. Thirty-two of these were located in Nevada and are presented in Figure 2. Two supplementary air sampling locations were established for the Phoebus 1-A Experiment and are shown in Figure 3.

All samplers were equipped with Whatman 541 prefilters. A portion of the routine samplers and both supplementary stations were equipped with MSA charcoal cartridges. All air sample prefilters and charcoal cartridges collected following the Phoebus 1-A test were returned to the Southwestern Radiological Health Laboratory in Las Vegas for analysis.

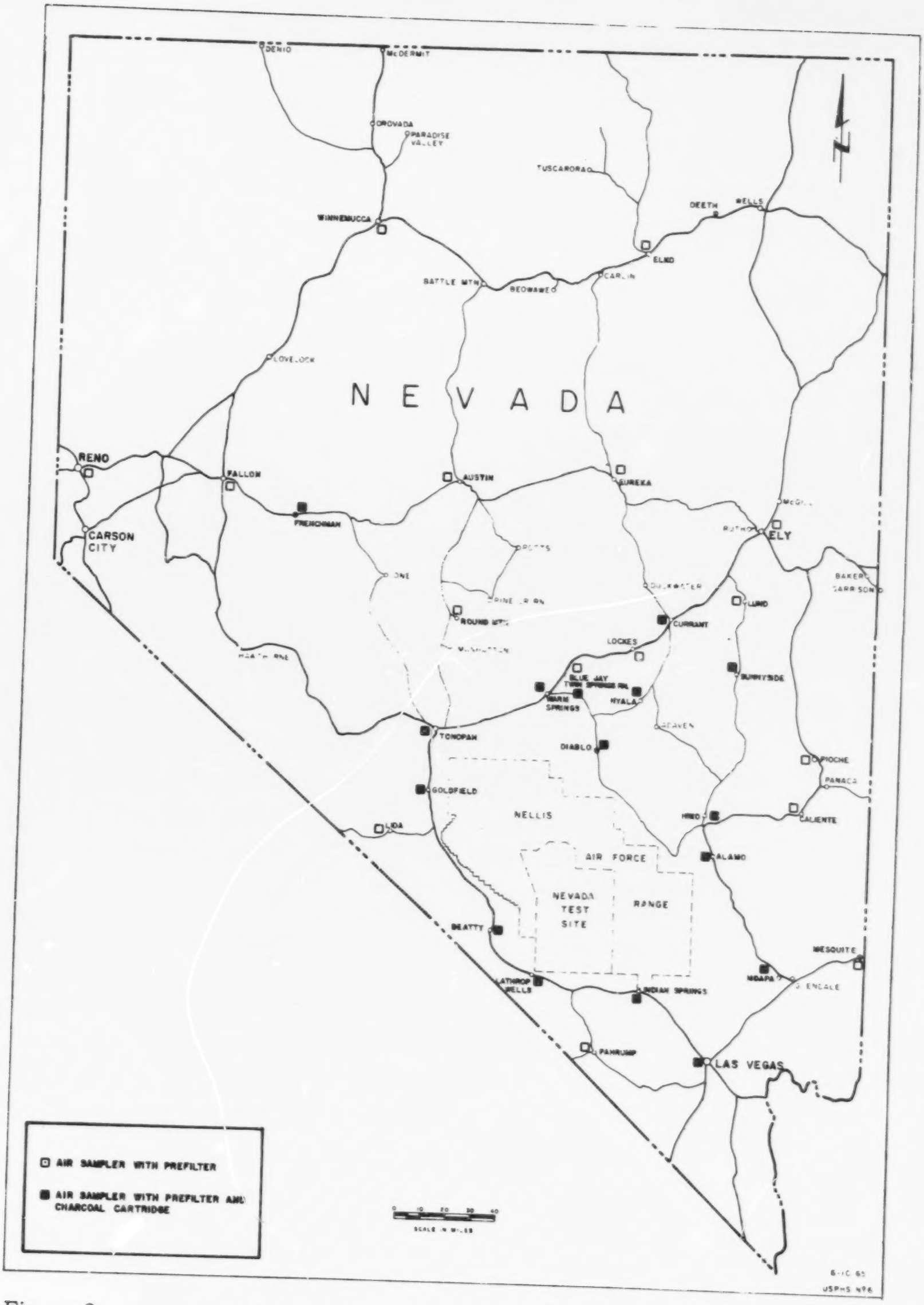

Figure 2. Air surveillance network stations in Nevada.

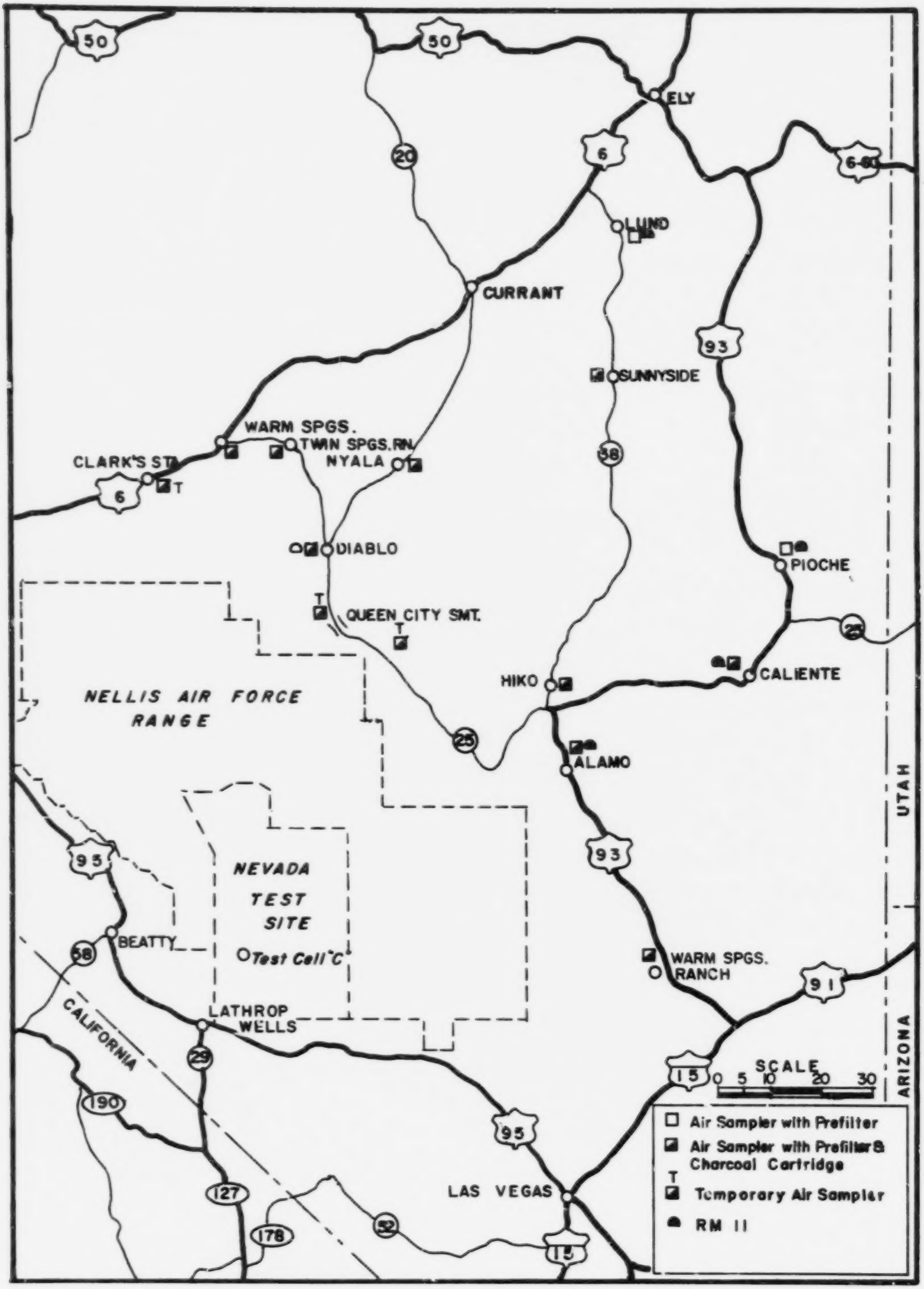

Figure 3. Special air sampling and dose rate recorder locations following Phoebus 1-A, EP4.

Prefilters were counted for gross beta activity, and simultaneously for gross alpha, with a Beckman "Wide Beta" proportional counting system. This system has an efficiency of approximately 45% for 0.54 Mev betas and a background of 6 $\pm$ 1 counts per minute. Gross beta concentrations were computed at the time of count for the purpose of screening samples and delineating the effluent trajectory.

Samples which were believed to contain fresh fission products were recounted several times within the first 48 hours. Based on these counts, an individual decay constant was computed for each sample. This constant was used to extrapolate the gross beta result to the end of the collection period.

Prefilters which indicated activity levels greater than 10 pCi/m^3 were analyzed for the biologically significant gamma emitting isotopes by placement directly upon a 4"x4" sodium iodide crystal. All reported values are corrected for the decay to the end of the collection period. Since it was not possible to define duration of effluent passage at all locations, the reported values given as pCi/m^3 assume an average concentration over each entire sampling period. Results are also reported in $\frac{\text{pCi-sec}}{m^3}$ to indicate the potential gross beta inhalation exposure at each location. This unit is obtained by multiplying pCi/m^3 by the sampling time in seconds.

All charcoal cartridges and some prefilters were analyzed for gamma isotopes by placing each directly on a 4"x4" sodium iodide crystal coupled to a 400-channel pulse height analyzer set to view energies from 0 to 2 Mev. The activity on the cartridge should represent primarily the gaseous radioiodines. Calculations were performed by an IBM 1620, utilizing a matrix technique. This method compensates for the mutual interference between isotopes for a given spectrum by the simultaneous solution of n equations

containing n unknowns, where n represents the number of isotopes for which solution is sought. Due to time and memory limitations on the 1620, a value for $n \leq 8$ is employed. The input to the computer program is variable so that solution may be made for any eight isotopes for which standard spectra are available. While this method is preferable to others for which it is practical to use the 1620, it is impossible to calculate an error interval.

Threshold detectability of several radionuclides is presented in Table 1 and is the result of an examination of previous data collected under the following:

a. Count time in days after fissioning as indicated by footnotes.

b. Prefilters collect unfractionated fission products resulting in a complex sprectrum.

c. MSA charcoal collects gaseous fission products only (primarily iodines).

d. An eight isotope matrix is employed for computation and isotopes other than those examined are present in amounts which are small relative to those eight.

e. Natural activity on air samples is approximately five times system background.

Table 1. Threshold detectability at time of count of several radionuclides in air samples (90% confidence level).

Sample Type	^{131}I	^{132}Te-I	^{133}I	^{135}I	^{140}Ba-La	Length of Count	Notes
Whatman No. 541	500	1000	500	1000	500	10 min	1
(pCi)	200	-	200	-	200	10 min	2
MSA Charcoal	200	400	200	400	200	10 min	1
(pCi)	100	-	100	-	100	10 min	2

1 - counted at less than 3 days after fissioning.
2 - counted at 3 days or more after fissioning.

Milk and Water Samples

After the release of activity from NRDS, milk samples were collected from three dairy farms and several farms producing milk for their

own consumption. Each milk sample is counted for 40 minutes using a 400-channel analyzer viewing an energy range from 0 to 2 Mev. All liquid samples are counted, with no prior preparation, in 3.5 liter inverted well aluminum beakers which are placed over a 4" x 4" sodium iodide crystal. The lower limit of detection for ^{131}I and ^{133}I in milk and water is 20 pCi/l at time of count, and all results below that value are reported as non-detectable. The reported values have, at time of count, a 2 sigma error estimate of $\pm$ 15 pCi/l or $\pm$ 10%, whichever is greater.

Vegetation Samples

Vegetation samples were collected in the suspected effluent trajectory to indicate deposition on the ground. They were also obtained at most milk sampling locations, with an effort made to make the sample representative of the cows' feed. These samples were taken as early indicators of where milk might be contaminated and were not intended to yield intake-excretion data. For this reason the vegetation sample results are reported simply as fresh fission products present or not present.

II. RESULTS

Experimental Plan 4 was conducted in the approximate time interval 1315 to 1326 hours PDT on June 25, 1965. A summary of meteorological conditions on the test day is presented in Table 2.

Heavy rain showers in the area north of NRDS limited aerial tracking of the effluent; however, initial on-site tracking of the effluent indicated a 0° bearing. Off-site environmental monitoring indicated contamination in the sector of 10° to 50°.

A. GROUND MONITORING

A ground monitor assigned to Queen City Summit (65 miles, 15° from Test Cell C) detected cloud arrival at 1615 PDT and measured a peak dose rate of 0.065 milliroentgens per hour at 1631 hours. Dose rates above background persisted at this location and are believed to have been associated with heavy rain in the area. Monitoring of Highway 25 north and south of Queen City Summit on the evening of June 25 indicated that this location was on the hot line. Queen City Summit is unpopulated.

B. DOSE RATE RECORDERS

Dose rate recorder data collected from Diablo on June 26 indicated a cloud arrival time of 1630 PDT on June 25, 1965. A net peak dose rate of 0.05 mR/hr occurred at 1700 PDT. The dose rate thereafter decayed as $t^{-1.15}$. During previous reactor tests dose rates following cloud passage have dropped sharply; however, "rainout" of fission products in the Diablo area was probably the cause of the sustained dose rates greater than the normal background of 0.025 mR/hr.

Table 2. METEOROLOGICAL DATA

PHOEBUS 1-A, EP4

Full Power Test, June 25, 1965

Sky condition : Brkn. Brkn.

Clouds : .6 Cumulonimbus, .3 Cirrus

Visibility : Unrestricted

Upper air data at: Jackass Flats, Nevada, 1310 PDT, 6/25/65

Height (Ft. MSL)	Wind (Deg/Kts)	Pressure (mb)	Temperature (°C)	Dew Point (°C)	Relative Humidity (%)
SFC	040/08	881	24.6	4.4	27
3615	070/07	870	23.3	4.3	29
4000	140/07	839	20.3	3.5	33
5000	190/10	808	17.0	2.2	37
6000	190/12	780	13.7	1.0	42
7000	190/13	750	10.0	-0.2	49
8000	200/13	724	7.4	-0.8	56
9000	200/13	700	4.8	-1.6	63
10000	200/13	673	1.9	-3.0	70
11000	210/13	648	-0.7	-4.2	77
12000	210/13	622	-2.3	-5.2	80
13000	210/13	599	-4.0	-6.3	84
14000	220/13	577	-5.1	-7.1	86
15000					

SFC=surface

The recorder data indicated a return to the background level on June 26. The exposure dose to Diablo due to cloud passage, assuming a one hour passage time, was calculated to be 0.04 mR, and the infinite dose due to deposition was estimated to be 1.2 mR. Diablo was the only populated location that received a measurable external dose. Recorder data collected from Alamo, Caliente, Pioche and Lund did not indicate dose rates greater than background.

C. FILM BADGES

Due to the low dose rates encountered off the test range complex following the Phoebus 1-A test, no film badges were collected immediately following the experiment. Film badges collected since the test date have not indicated exposures that could be attributed to the Phoebus 1-A test.

D. AIR SAMPLES

Charcoal cartridges collected from four locations following Phoebus 1-A contained isotopes of radioiodine. The analyses are presented in Table 3. Cartridges collected from Twin Springs Ranch, Warm Springs, Clark Station, Nyala, Currant, Sunnyside, Caliente, and Warm Springs Ranch did not contain radioiodines. Gross beta analysis of prefilters from these locations did not indicate concentrations greater than normal background levels (<2 pCi/m^3), although strontium-91 was detected on several prefilters in concentrations of approximately 1 pCi/m^3.

E. WATER SAMPLES

Water samples collected from several potable supplies following the experiment contained ^{131}I. Iodine-133 was not detected in any

Table 3. Analyses of air samples collected following Phoebus 1-A, EP4.

Location (See Figure 3)	Air Volume (m^3)	Date Time On	Date Time Off	Gross Beta Activity Prefilter at End of Collection (pCi/m^3)	Gross Beta Activity Prefilter at End of Collection ($\frac{pCi\text{-}sec}{m^3}$)	Collector	Gamma Pulse Height Analysis Activity (pCi/m^3) at end of collection ^{131}I	^{132}I	^{133}I	^{135}I
Queen City Summit (unpopulated)	53	6/25 1551	6/26 1145	1.6	1.15×10^5	P	--	--	--	--
						C	7.7	3.6	22	15
Diablo	541	6/25 0700	6/26 0920	.46	4.36×10^4	P	--	--	--	--
						C	.63	.87	2.1	1.3
Alamo	482	6/25 0700	6/26 0730	2.0	1.76×10^5	P	1.1	2.1	2.5	ND
						C	.56	.21	1.8	1.2
Hiko	499	6/25 0805	6/26 0810	1.4	1.22×10^5	P	.6	1.4	1.5	ND
						C	.36	.24	1.0	.34
AEC Standards for Radiation Protection							100	8000	1000	4000

-- = gamma pulse height analysis not performed.
ND= not detectable
P = prefilter
C = charcoal cartridge

of the samples. The results of the analyses are presented in Table 4. The contamination found in the water could possibly reflect "rainout" and subsequent runoff into water supplies.

Table 4. Potable water samples collected following Phoebus 1-A, EP4

Location (See Figure 4)	Date Collected	Radioassay Data pCi/l ^{131}I
Caliente	June 28	160
	July 7	100
	Aug 4	ND
Pioche	June 28	50
	July 7	ND
Twin Springs Ranch	July 7	60
	July 28	ND
Blue Jay Maint. Station	July 7	160
	July 28	ND
Warm Springs Ranch	June 28	130
	Aug 4	ND

F. MILK SAMPLES

Milk was sampled at several locations following the Phoebus 1-A test. The results of the analyses are presented in Table 5. Several samples were obtained prior to the effluent passage, as denoted by an asterisk in the date column. The data indicate that radioiodine contamination of the area northeast of the test range complex existed prior to the Phoebus effluent passage. This contamination is believed due to three prior events: (1) a Chinese mainland nuclear detonation on May 14, 1965 which introduced low levels of ^{131}I into milk supplies over much of the United States, (2) a test of the nuclear rocket NRX-A3 which was conducted at NRDS on May 20, 1965, and (3) an accidental release of fission products from the Diluted Waters event conducted at NTS on June 16, 1965. The latter two events are

Table 5. Analysis of milk samples collected following Phoebus 1-A, EP4.

Location (See Figure 4)	Date Collected	Type of Feed: Hay	Type of Feed: Pasture or Gr. Chop	Presence of Radioiodine in feed	Gamma Ray Pulse Height Analysis: ^{131}I	Gamma Ray Pulse Height Analysis: ^{133}I
Stewart's Dairy Alamo	6/25/65*	x	x	ND	ND	ND
	6/26			P	ND	ND
	6/28			P	20	ND
	6/29			--	20	ND
	7/02			P	20	ND
	7/04			--	50	ND
	7/05			--	ND	ND
	7/07			ND	30	ND
	7/15			ND	ND	ND
Schofield Dairy Hiko	6/25/65*		x	ND	30	ND
	6/26			P	40	ND
	6/28			P	50	40
	7/02			ND	60	ND
	7/07			ND	ND	ND
Blue Eagle Rn. Currant	6/28/65	x	x	P	100	ND
	7/01			--	180	ND
	7/03			P	50	ND
	7/04			--	50	ND
	7/05			--	30	ND
	7/07			P	60	ND
	7/18			--	ND	ND
Manzonie Rn. Currant	6/19/65*	x		P	50	ND
	6/28			ND	20	ND
Sharpe Ranch Nyala	6/29/65	x		P	ND	ND
	7/07			ND	ND	ND
Young Ranch Caliente	6/28/65	x	x	P	ND	ND
	7/06			ND	ND	ND
Horlacher Rn Pioche	6/28/65	x	x	--	ND	ND
	7/07			--	ND	ND
McKenzie Dairy Lund	6/28/65	x		ND	ND	ND

* samples obtained before Phoebus effluent passage
-- no sample collected
ND = not detectable
P = present

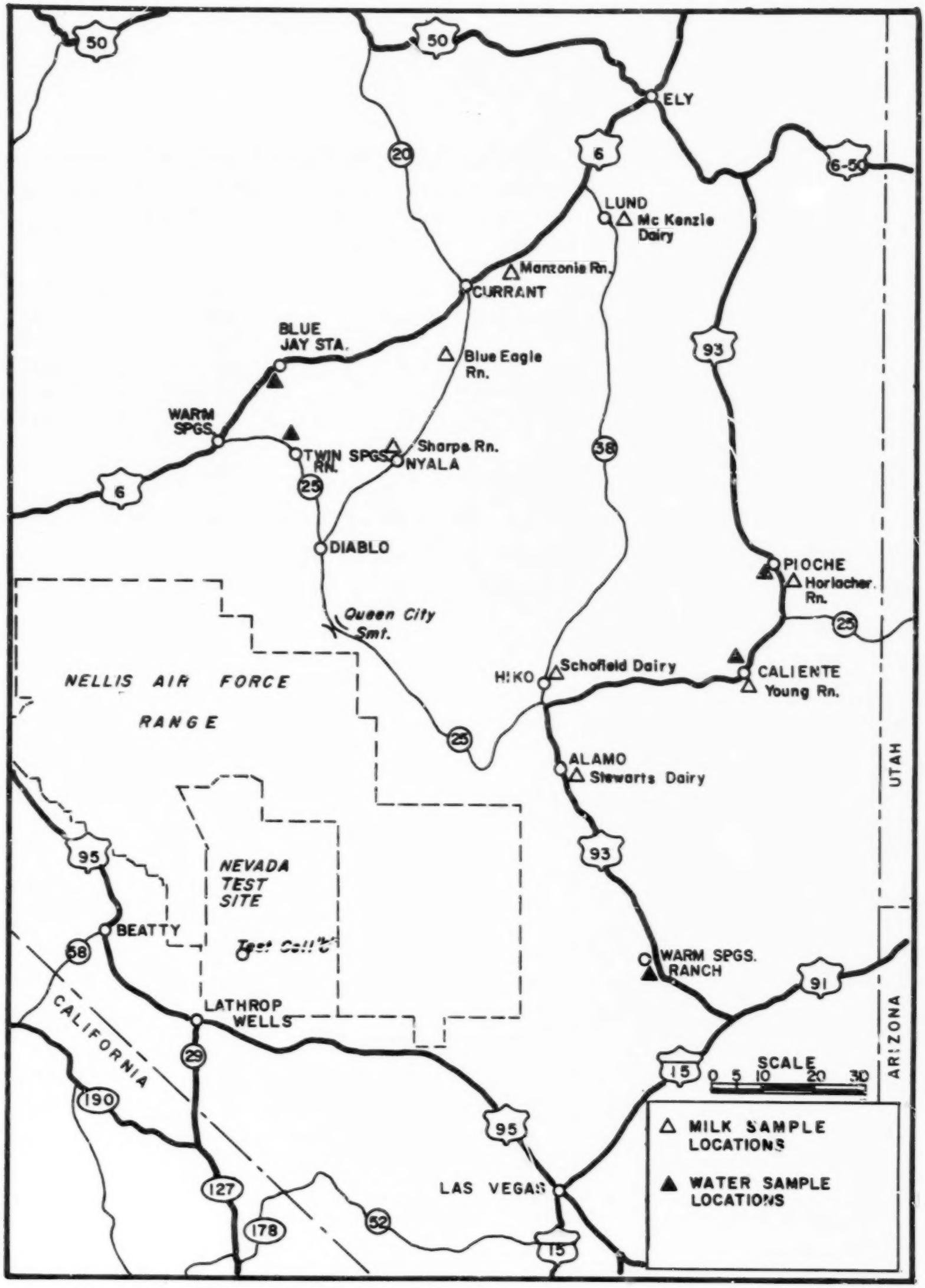

Figure 4. Milk and water sampling locations following Phoebus 1-A, EP4.

reported in SWRHL-18r and the PHS interim report for the Diluted Waters event, issued November 15, 1965. Some contamination, however, must be attributed to the Phoebus effluent since ^{131}I levels increased and the presence of ^{133}I ($T_{1/2}$ = 20 hrs) and ^{132}Te-I ($T_{1/2}$ = 77 hrs) was noted on feed samples.

G. VEGETATION SAMPLES

Positive evidence of effluent passage and deposition, as determined by the presence of ^{91}Sr on vegetation, was obtained at Diablo, Queen City Summit, and Hiko. Many vegetation samples contained fission products of intermediate age such as ^{140}Ba-La and ^{95}Zr-Nb. This contamination may also be associated with the events discussed above.

III. CONCLUSIONS

The effluent from the Phoebus 1-A Experiment was detected off the test range complex, but the levels represented small fractions of the guides cited in the AEC Standards for Radiation Protection, AEC Manual, Chapter 0524[1].

The radiation dose standard for external whole body exposure to an individual is 500 millirem per year. As discussed on page 12, the only populated location to receive an external dose was Diablo, where 0.04 mR was due to cloud passage and 1.2 mR was due to deposition.

The iodine air concentrations as measured by charcoal cartridges off the test range complex are presented in Table 3. Also presented are the AEC standards for soluble iodine concentrations. The standards represent concentrations of radioactivity that should not be exceeded on a continual basis. For the purpose of applying these standards, radioactive concentrations in effluents may be averaged over periods up to one year. Since the levels presented in Table 3 did not exist longer than 27 hours in any instance, it is evident that the concentrations represented a small fraction of the protection standards.

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(1) U. S. Atomic Energy Commission Manual Chapter 0524, Standards for Radiation Protection.

The charcoal measured iodine concentrations presented in Table 3 may also be expressed in pCi-sec/m^3. By applying the appropriate conversion factors developed by R. S. Decker[2] an estimate of the potential thyroid dose may be calculated. The conversion factors for ^{131}I and ^{133}I are 3.24×10^{-7} and 9.21×10^{-8} millirad/pCi-sec/m^3 respectively. The doses due to ^{132}I and ^{135}I inhalation are negligible. The potential inhalation dose to any off-site location following Phoebus 1-A was calculated to be less than 0.1 mR. This may be compared to the AEC standard for thyroid exposure to an individual which is 1500 millirem per year.

As seen in Table 4, water samples from five locations contained ^{131}I. The values are all below 300 pCi/l of ^{131}I, the AEC protection standard for continuous exposure. The contamination cannot be positively identified with Phoebus effluent since ^{133}I was not detected in the June 28 samples. In addition, air sampling and ground monitoring data indicate that Warm Springs Ranch was not in the effluent trajectory; therefore, it is probable that a fraction of the ^{131}I in water from that and other locations was due to one of the three sources previously mentioned - the Chinese mainland detonation, the NRX reactor run, and the Diluted Waters event.

Milk sampling following Phoebus 1-A indicated contamination due to the effluent deposition. If one scales directly from data in FRC Report No. 5[3], Table 1, it can be calculated that a dose of 21 millirad could have been delivered to the thyroids of residents at Blue Eagle Ranch. The dose prediction assumes the conditions

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(2) "Radiological Prediction and Monitoring of Tests at the Nuclear Rocket Development Station", P. Griffiths and P. Erickson, Space Nuclear Propulsion Office--Nevada, November 1965.

(3) "Background Material for the Development of Radiation Protection Standards" Report No. 5 of the Federal Radiation Council, July 1964.

presented in FRC No. 5 and that the contamination was the result of Phoebus deposition alone. As discussed in the milk results section, the latter assumption is probably not precise. The 21 millirad value represents 1.3% of the 1500 millirem standard.